Parameter Estimation of Motion Blurred Insulator Image Based on Insulator Water Hot Washing Application

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Abstract

In recent years , the insulator water hot washing vehicle has become a new method to clear insulator pollution. The pollution of the insulator can be monitored, and the blurred image restoration is an important step for the insulator image pollution judgment. Under the assumption of uniform linear motion blurred image and from the point of view of the Fourier transform, this paper will take theoretical analysis of the stripe characteristics and the direction characteristic of insulator blurred image's point spread function in frequency domain. It introduces the mathematical principles of the Radon transform and ideas and steps to estimate motion blur direction and blur scale . Aimed at cross-shaped bright lines in Fourier spectra of actual insulator blurred image, a sub-block algorithm is proposed. The experimental results show the effectiveness of the algorithm.

Keywords

Blurred Image Restoration; Radon Transform; Sub-block Algorithm;Water Hot Washing

Introduction

Numerous varieties of insulator largely used in a part of the power grid play an important role in the transmission line. On the one hand, it provides mechanical support for the transmission of current conductor; on the other hand, it prevents the formation of ground channel for current grounding ,for insulation effect. In the long run, however, dust particles deposit to its surface and form the impurity layer formation. In the fog, dew, rain or snow, the electrolyte of the impurity layer wets, the surface conductivity increases, the insulation performance comes low, and the moisture of ash content dissolves more electrolyte, causing the flashover discharge of the insulator surface, which is referred to as pollution flashover. Large area pollution flashover blackout accidents are catastrophic accidents, which cause heavy losses to the electric power enterprises and the national economy. In order to prevent the insulator pollution flashover from causing power outages and break accidents, we must strengthen the insulator anti-pollution flashover work.

Reliable detection and on-line monitoring of insulator pollution degree is a very important part of the anti-pollution flashover work. In recent years, the water hot washing vehicles develops fast at home and abroad. It is an extremely effective method to take photos by installing cameras on the washing vehicle, and to detect the insulator pollution degree by processing images. In the working time, however, the vehicle body is in vibration state, which inevitably impacts the insulator image resolution, and the image clarity directly related to the judgment of insulator pollution degree, so the blurred insulator image restoration is an indispensable and important work. This paper mainly studies the insulator blurred image and restoration method of the insulator blurred image.

Mathematical Model of Motion Blur Degeneration and Spectrum Characteristic

Cameras of the water hot washing vehicles are in vibration state, we see them as a uniform linear motion which belongs to linear shift -invariant system, the acquired image $g(x,y)$ can be expressed as:

$$g(x,y)=h(x,y)*f(x,y)+n(x,y) \quad (1)$$

In which, $h(x,y)$ represents the degradated point spread function(PSF), $f(x,y)$ represents the definition image, and $n(x,y)$ for the additive noise interference. This is the degeneration model of linear shift-invariant system.

Considering the noise does not exist, to the blur caused by uniform linear motion, PSF can be described as:

$$h(x,y)=\begin{cases}\frac{1}{L}, & 0\le x\le L\cos\theta, 0\le y\le L\sin\theta\\ 0, & \text{others}\end{cases}$$

Where, θ is blur angle, that is the angle between the direction of movement and the horizontal axis; L is motion blur scale, that is the pixels moving distance in the direction of movement. The larger L is,the bigger the blur scale is.

For the ease of analysis, assumed that the image moves L pixels in the horizontal direction, then $h(x,y)$ turns to:

$$h(x,y)=\frac{1}{L}, 0\le x\le L, y=0 \quad (2)$$

Assume that the image size is $N\times N$, do two-dimensional discrete fourier transform to the formula (2), we can get:

$$H(u,v)=\frac{1}{N^2}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}h(x,y)e^{-j2\pi(\frac{ux}{N}+\frac{vy}{N})}$$

$$=\frac{1}{LN^2}\frac{1-e^{-j2\pi(\frac{uL}{N})}}{1-e^{-j2\pi(\frac{u}{N})}} \quad (3)$$

The formula (3) shows that when $\frac{uL}{N}$ is an integer, $H(u,v)$ equals to 0; in the spectrum, for every $\frac{N}{L}$ column there will be a value of 0. In grayscale , there will be a number of parallel dark stripes. For non-horizontal direction of motion-blurred image, according to the spectrum characteristic of fourier transform, dark stripes are perpendicular to the direction of motion. According to the spectrum of isotropic of original image, the blurred image $g(x,y)$ has the similar spectrum characteristic with $H(u,v)$, and the the fringe spacing is $\frac{N}{L}$. So the blur direction and blur scale can be determined according to the stripes characteristics of the spectrum of the blurred image. As shown in fig.1.

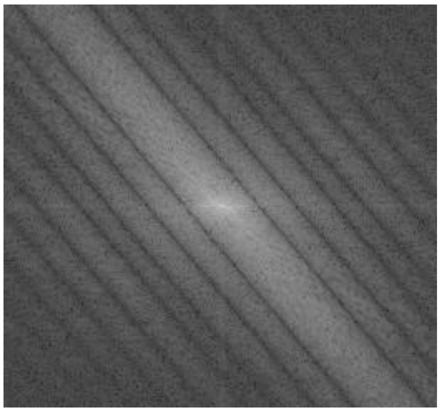

FIG. 1 SPECTRUM CHARACTERISTIC OF THE BLURRED IMAGE

Envelope of $H(u,v)$ is

$$|H(u,v)|=\left|\frac{\sin(\pi uL)}{\pi uL}\right|$$

From above we can conclude that $H(u,v)$ has the characteristic of sampling function, and it is an even function, according to the fourier transform reciprocity, by doing fourier transformation to $|H(u,v)|$,bright stripes will appear with the same direction of $h(x,y)$ after fourier transformation. According to the original image spectrum of isotropic, similarly there is a straight line in the θ direction by fourier transformation of $|G(u,v)|$, the blurred image spectral envelope. As shown in fig.2.

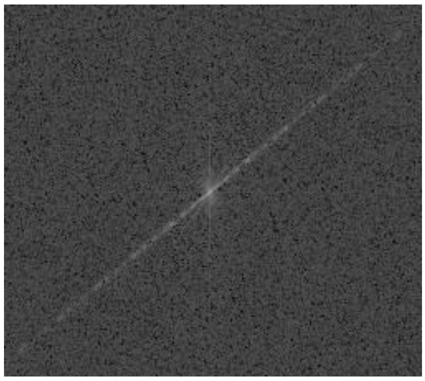

FIG. 2 FOURIER TRANSFORMATION FIG. OF $\log|G(u,v)|$

Motion Blur Parameter Estimation

To find out the direction of spectrum dark lines , we can use the hough transform, robust regression and linear fitting method. However, these methods usually require a number of candidate points for fitting a straight line , this often image binary to get points on the line (boundary points). However , it is not easy to select the appropriate threshold to accurately distinguish between a point on a straight line with a

point on the non-linear , and the threshold is typically not the same on the type of image , if the threshold selection is somewhat inappropriate , it may cause a lot of errors candidate point . So this article uses the radon transform to detect straight line. Radon transform is more complex than hough transform complex, but it can be more effective to detect a straight line , its biggest advantage is that it does not need designated candidate points like the hough transform .

Radon Transform Principle

The radon transform is used to calculate the projection of the image matrix in the specified direction , that the line integral of the binary function $f(x,y)$ in a certain direction . The projection is movable along an arbitrary angle, the radon transform of $f(x,y)$ is the line integral of $f(x,y)$ which is parallel to the y' axis , i.e.

$$R_\theta(x') = \int_{-\infty}^{\infty} f(x'\cos\theta - y'\sin\theta, x'\sin\theta + y'\cos\theta)dy'$$

Where

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

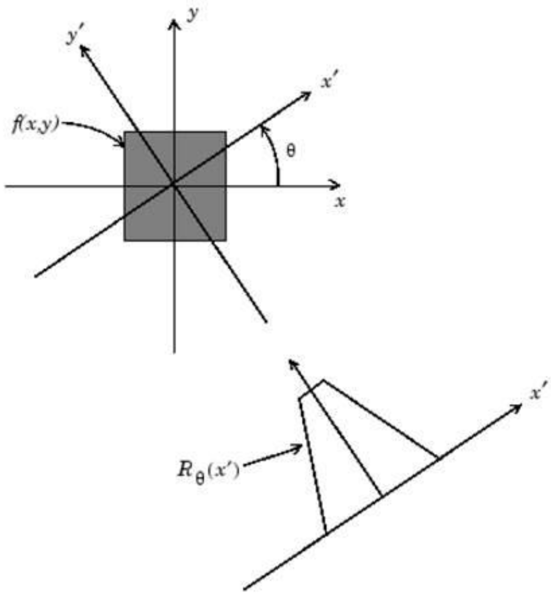

FIG. 3 RADON TRANSFORM SCHEMATIC DIAGRAM IN AN ARBITRARY ANGLE

Radon transform schematic diagram in an arbitrary angle as is shown in fig.3. for an image, when θ is a certain value and x' is taken over all values, we can obtain the projection values in the direction of θ; by changing the value of θ, the projection image can be obtained in different directions ; then change the value . Obviously, when the image contains a linear component, there will be extrema of the radon transform value in the corresponding angle in this straight line.

The Direction of The Motion Blur Estimation

According to the physical significance of the radon transform, a high gradation value line in the image will form a bright spot on the x' plane; low gray value line will form a dark spot. The detection of a straight line in the image plane is transformed to the detection of the bright and dark points in the parameter plane .

Do radon transform to the image from one to 180 degrees, the results can be represented in a matrix r . The matrix has 180 columns, each column vector is the projection value of the image integration at an angle along a family of straight-line. Blurred image spectral has stripes characteristics, so there should be a maximum in the projection vector corresponding to the maximum angle is the angle of the stripes . From the above, we can conclude that the main steps of the algorithm are as follows:

(1) Through the two-dimensional fourier transform . Seeking a motion-blurred image amplitude spectrum $|G(u,v)|$, centralize $|G(u,v)|$; perform a logarithmic calculation on $|G(u,v)|$ to compress spectrum dynamic range;

(2) Do fourier transformation to $\log|G(u,v)|$,perform a logarithmic calculation after centralizing, and do radon transform from one to 180 degrees.

(3) Find the maximum value of the transformation matrix r, and the number of columns of the maximum is the blurred movement angle .

Motion Blur Scale Estimation

According to the above analysis, the spectrum of the blurred image has stripes characteristics and the spacing of the stripes is $s = \frac{N}{L}$. So the fringe spacing s can be determined in accordance with the spectrum of the blurred image, thus L obtained, i.e.fuzzy scale.

In section 3.3, the direction of the straight line in the blurred image spectrum is detected by the radon transform,i.e. The blur direction θ . Do θ angle of rotation on the blurred image spectrum, and incremental projection of all the pixels in the

horizontal axis direction, getting the distance between the adjacent minimum value point of the curve, that is, the stripe width s. For the actual image can not be the ideal sinc function curve, there being many glitches, we need to smooth it at first, and then calculate the minimum spacing, and take the average value of a plurality of spacing to increase the accuracy of the spacing, to get the fringe spacing s. Finally, use $L = \frac{N}{s}$ to obtain motion blur distance.

Motion-blurred Image Spectrum Block Processing

In practice, due to the limited space of the camera imaging, the resulting blurred image spectrum showed in figure 4 has not clear enough stripes characteristics and owns edge truncation compared to the ideal burred image spectrum, so there appear lighter cross stripes in the centralized spectrum. So it's necessary to do the image block and remove the bright stripes.

Firstly, estimate the width of the horizontal, vertical bright line. For a vertical bright line with the image size n, search the picture from central to both sides to take the first four pixels of each column and get the average value. If it's bigger than the threshold value and the distance between the former bright line is less than 10 pixels, we consider it as one of the center vertical bright line, and finally get the width of vertical bright line; similarly the width of the horizontal bright line can be obtained. We chose the greater one as the bright line width.

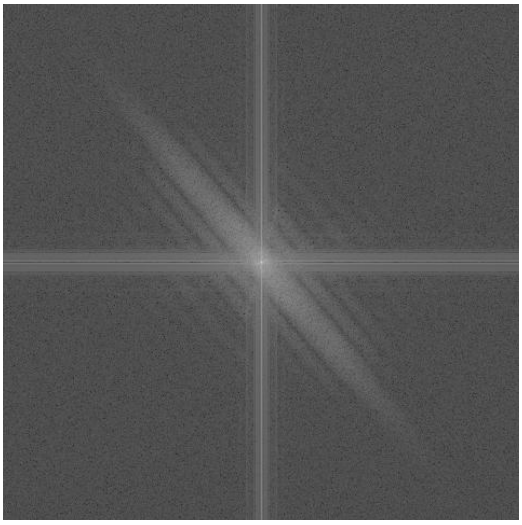

FIG.4 SPECTRUM OF THE ACTUAL BLURRED IMAGE

Under the conditions of removal of the bright lines, block the motion blur spectrum image into the upper left, upper right, lower left and lower right. For the block with more bright lines, the sum of the gradation value is bigger, so we calculate the gray values of the sub-block respectively and identify the block with the most obvious contrast of light and dark stripes. When the image is large, we can take the sub-block by taking the center of the image as the center of the sub-block before blocking, in order to reduce the computational amount.

Experimental Results and Analysis

This experiment use the clear insulator image as the standard image, simulate uniform linear blurred motion by matlab simulation, and use the method above to estimate the blur direction and fuzzy scale. The results are shown in Table 1:

TABLE 1 BLURRED MOTION PARAMETER ESTIMATION RESULTS

angle (degree)	scale (pixels)	Estimated angle (degree)	error (degree)	Estimated scale	error (pixels)
10	10	9	-1	8.14	-0.76
20	20	19	-1	19.96	-0.04
30	20	31	1	15.54	-4.46
40	20	40	0	15.54	-4.46
20	30	20	0	30.51	0.51
30	30	30	0	30.73	0.73
40	30	41	1	32.86	2.86
20	40	20	0	42.15	2.15
30	40	29	-1	41.6	1.6
40	40	38	-2	40.3	0.3

It can be seen from table 1 that the direction angle error is all less than two degrees, and the distance error is also relatively small. Because of the interception of image, when the fringe spacing is relatively wide, i.e. The fuzzy scale is relatively small , dark stripes of the interception area is less, and the error will be relatively large.

Fig.5 is a reducing effect of blurred movement simulation of clear insulator image. The fuzzy angle is 20 degrees, and the fuzzy scale is 20 pixels. As can be

seen, the recovery is good.

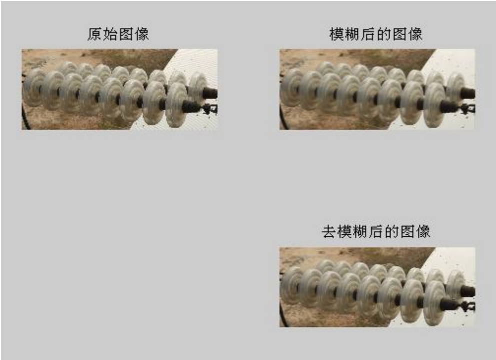

FIG. 5 THE RECOVERY EFFECT IMAGE OF BLURRED MOVEMENT SIMULATION OF INSULATOR IMAGE

Conclusion

Blurred image restoration is an important step for judging insulator pollution. In this paper, aimed at the motion-blurred images stripes characteristics in frequency spectrum and the actual image chopping characteristics, we proposed a method based on sub-block of the radon transform method to estimate and simulate the direction and scale of the motion blur. Experimental results show that this method can effectively estimate the direction and scale of the motion blur, which can effectively remove the blur.

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